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Self-Driving Vehicles and Policy Implications: Current Status of Autonomous Vehicle Development and Minnesota Policy Implications

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Self-Driving Vehicles and Policy Implications: Current Status of Autonomous Vehicle Development and Minnesota Policy Implications

Adeel Lari,* Frank Douma** & Ify Onyiah***

ABSTRACT

Whether you call them self-driving, driverless, automated, or autonomous, these vehicles are on the move. Recent announcements by Google (which drove over 500,000 miles on its original prototype vehicles)¹ and other major automakers indicate the potential for development in this area. Driverless cars are often discussed as “disruptive technology” with the ability to transform transportation infrastructure, expand access, and deliver benefits to a variety of users. Some observers estimate limited availability of driverless cars by 2020, with wide availability to the public by 2040.

This Article includes examination of the current status of this technology, and the implications for road safety, capacity, travel behavior, and cost. This Article also considers the regulatory framework and policy challenges this technology may face. In particular, this Article presents a Minnesota perspective. As the Minnesota Department of Transportation implements the Twenty-Year Minnesota State Highway Investment Plan and establishes priorities for the next several decades, state officials need information about the potential for

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1. Google has since launched a fully autonomous prototype that does not allow human driving: it has no steering wheel, brake pedal, or accelerator pedal. Chris Urmson, *Just Press Go: Designing a Self-Driving Vehicle*, GOOGLE (May 27, 2014), <http://googleblog.blogspot.com/2014/05/just-press-go-designing-self-driving.html>.

this technology to transform Minnesota's transportation system. The Metropolitan Council also needs to pay serious attention, as self-driving cars can potentially change the way we live and travel within the Council's planning horizon. Additionally, Minnesota policymakers will need to consider whether current policy accommodates the deployment of this driverless technology. Finally, this Article summarizes the current consensus about self-driving vehicles, considers the implications for Minnesota, and suggests steps that policymakers in Minnesota can take to prepare for such technology.

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noted that self-driving vehicles may change not only the way we drive, but also how we use time and how urban landscapes are developed—and people are starting to take notice.⁸

The story goes that at the 1997 COMDEX computer conference Bill Gates made a stark comparison between the transformational and cost saving ability of the PC industry and the relative costs of the consumer automobile, due to lack of innovation.⁹ Detroit reportedly responded with comparisons of its own including: “Yes, but would you want your car to crash twice a day?”¹⁰ Despite these invectives, car manufacturers have found a way to incorporate more computer technology into their vehicles over the last several decades to enhance vehicle offerings.¹¹ Now, back-up cameras, assisted braking, GPS, and stability control systems come standard in many models and have improved performance and safety.¹² These lower level forays into computerized or smart vehicles signal the potential for a more cooperative relationship. With technology companies like Google developing their own self-driving technology for use in existing vehicle models, it appears that technology and car manufacturers may work together on SDV development.¹³ Whatever the reluctance in the past for innovative technology, some Detroit automakers appear ready to adopt a more

Bilger, *Auto Correct: Has the Self-Driving Car at Last Arrived?*, NEW YORKER (Nov. 25, 2013), <http://www.newyorker.com/magazine/2013/11/25/auto-correct>.

8. KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 3–4.

9. See Katie Hafner, *Do Computers Have to Be Hard to Use?*, N.Y. TIMES (May 28, 1998), <http://www.nytimes.com/1998/05/28/technology/do-computers-have-to-be-hard-to-use.html> (suggesting that if the auto industry had kept up with the computer industry, “people would all be driving \$27 cars”).

10. See *id.* (attributing the statement “to an auto maker”).

11. E.g., *GM Has Long Envisioned a Day When Cars Don’t Crash: Company Has Long History of Intelligent and Connected Driving Technology Development*, GEN. MOTORS (Sept. 7, 2014), <http://media.gm.com/product/public/us/en/technology/home.detail.html/content/Pages/news/us/en/2014/Sep/0907-its-history.html>.

12. E.g., *Guide to Safety Features: These Features Can Help Make Driving Safer*, CONSUMER REP., <http://consumerreports.org/cro/2012/04/guide-to-safety-features/index.htm> (last updated Jan., 2014).

13. See Aaron M. Kessler, *In Detroit, Google Makes a Case for Driverless Cars*, N.Y. TIMES (Jan. 14, 2015), <http://www.nytimes.com/2015/01/15/business/in-detroit-google-makes-a-case-for-driverless-cars.html> (“The Silicon Valley search giant is exploring the idea of teaming up with a traditional automaker to manufacture such a car . . . and is already in discussions with a number of them.”).

computer-like driving machine,¹⁴ perhaps leading to a scenario where traditional vehicles go the way of the horse and buggy of centuries past, and demonstrating the transformational ability of technology to change the way people move. 2013 turned into the year of the SDV, with manufacturers from Bosch to Mercedes to Tesla giving updates on their SDV plans.¹⁵ Government regulators, such as the National Highway Transportation Safety Administration (NHTSA), issued rules and recommendations for the potential SDV market.¹⁶ Often, 2020 is the most quoted time frame for the availability of the next level of SDVs, with wider adoption in 2040–2050.¹⁷ However, there are many obstacles to overcome to make this technology viable, widely available, and permissible. These include developing technology affordable enough for the consumer market, creating a framework to deal with legal and insurance challenges, adapting roadways to vehicle use if necessary, and addressing issues of driver trust and adoption of

14. *Id.*

15. Rory Carroll, *Tesla Enters Race to Build Self-Driving Car*, REUTERS (Sept. 17, 2013, 9:18 PM), <http://www.reuters.com/article/2013/09/18/us-tesla-selfdriving-idUSBRE98H01720130918>; Wayne Cunningham, *Bosch Self-Driving Car Spotted in California*, CNET (July 19, 2013, 6:29 PM), <http://www.cnet.com/news/bosch-self-driving-car-spotted-in-california/>; David Undercoffler, *Mercedes-Benz Reveals Recent Test of Self-Driving Car*, L.A. TIMES (Sept. 10, 2013, 5:00 AM), <http://www.latimes.com/business/autos/la-fi-hy-autos-mercedes-autonomous-car-20130909-story.html>.

16. See NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEP'T OF TRANSP., PRELIMINARY STATEMENT OF POLICY CONCERNING AUTOMATED VEHICLES (2013) [hereinafter NHTSA PRELIMINARY STATEMENT], available at http://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf.

17. *E.g.*, *How Autonomous Vehicles Will Shape the Future of Surface Transportation: Hearing Before the Subcomm. on Highways & Transit, H. Comm. on Transp. & Infrastructure*, 113th Cong. 20 (2013) [hereinafter Statement of Hon. David L. Strickland] (statement of Hon. David L. Strickland, Administrator, National Highway Traffic Safety Administration); *id.* at 13 (statement of Raj Rajkumar, Professor, Electrical & Computer Engineering Department, Carnegie Mellon University) (“[C]hallenges should not deter policymakers from pursuing the goal of autonomous vehicles because this technology holds tremendous promise to reduce highway spending in the 2030–2040 timeframe.”); KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 22 (showing a potential timeline for self-driving applications in 2025); TODD LITMAN, VICTORIA TRANSP. POLICY INST., AUTONOMOUS VEHICLE IMPLEMENTATION PREDICTIONS: IMPLICATIONS FOR TRANSPORT PLANNING 14 (2015), available at <http://www.vtpi.org/avip.pdf>.

the new technology.¹⁸ There is even some question as to who will be considered the “driver” in the self-driving realm.¹⁹

For Minnesota, there are unique challenges and opportunities to be addressed. In addition to building upon the national discussion above, this Article will consider Minnesota’s driving statutes, road and driving conditions, and how current highway development plans might interact with driverless technology.

II. HISTORY AND TERMINOLOGY

It was only a few decades after the introduction of the first Model T Ford that people began to think about an automated version of the passenger vehicle.²⁰ Throughout the ensuing decades, automotive and technology magazines documented the possibilities and those working to create “the car that drives itself.”²¹ In the 1950s, researchers from the major car brands worked on a system of roadway and car modifications they hoped would result in such a development.²² Television shows such as the 1980s *Knight Rider* helped to instill the SDV movement in the American imagination.²³ Universities and governments worked on projects to deliver the real thing.²⁴ During this same time, cars were advancing with new transmissions, more powerful engines, and sleeker makes.²⁵

18. FAGNANT & KOCKELMAN, *supra* note 7, at 10–14.

19. KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 21.

20. Harry McCracken, *Look Ma, No Hands! A Brief History of Self-Driving Cars*, TECHNOLOGIZER (Oct. 9, 2010, 3:17 PM), <http://www.technologizer.com/2010/10/09/google-self-driving-cars/> (discussing the first attempts at creating automated vehicles).

21. E.g., Martin Mann, *The Car that Drives Itself*, POPULAR SCI., May 1958, at 75, 75, available at <http://www.popsoci.com/archive-viewer?id=xiUDAAAAMBAJ&pg=75>.

22. McCracken, *supra* note 20.

23. See Ian Bogost, *The Secret History of the Robot Car: How Self-Driving Vehicles Took Off*, ATLANTIC (Oct. 14, 2014, 8:05 PM), <http://www.theatlantic.com/magazine/archive/2014/11/the-secret-history-of-the-robot-car/380791/> (“As autonomous vehicles like . . . *Knight Rider*’s KITT graced the . . . small screens, researchers’ efforts began to bear fruit.”).

24. E.g., C. P. Gilmore, *How You’ll “Drive” the Amazing URBMOBILE*, POPULAR SCI., Oct. 1967, at 75, available at <http://www.popsoci.com/archive-viewer?id=1SoDAAAAMBAJ&pg=75>.

25. See Damon Stetson, *High-Power Cars Defended by G.M.*, N.Y. TIMES, Aug. 28, 1956, at L29, available at <http://query.nytimes.com/mem/archive/pdf?res=990CE4D61E3FE03BBC4051DFBE66838D649EDE>; Reginald Stuart, *Technology to the Rescue in a Year of Crisis*, N.Y. TIMES, Oct. 26, 1980, at S17,

The most ambitious claimed that SDVs were just around the corner.²⁶ In the 1960s, a grant from the U.S. federal government set a goal of 1985 for a self-driving prototype.²⁷ Later, in 1991, the U.S. Congress instructed the Department of Transportation (DOT) to engage in research to develop more “intelligent vehicle-highway systems” as a part of the surface transportation infrastructure.²⁸ This included transferring federal technology to state and local governments and investing funds in research around the country.²⁹ One of the most high profile developments in federal support for the industry was in the form of the Defense Research Advanced Projects Agency (DARPA) Grand Challenge in 2004, 2005, and 2007, which provided a lead prize of \$1 million for a driverless vehicle.³⁰ This project brought together teams from around the world in the United States, but work was also completed and technology advanced by governments, universities, and car makers in countries from Japan to Europe.³¹ Indeed, those who participated in these challenges still form some of the core researchers and engineers seeking to make SDVs a reality in their lifetimes.³² For decades, people claimed the breakthrough was imminent. Now, it appears, it finally has arrived.

Given the variously dispersed actors working on self-driving technology, it is no wonder that while the goals are similar, the name is not. From self-driving, which will be the term used in this Article, to driverless, autonomous, auto-pilot,

available at <http://query.nytimes.com/mem/archive/pdf?res=9800E1D81238E232A25755C2A9669D94619FD6CF> (discussing design and technology improvements in new models of cars in the 1980s).

26. See Gilmore, *supra* note 24, at 75 (discussing a collaboration between the Cornell Aeronautical Laboratory and the U.S. Department of Housing and Urban Development to design and implement the Urbmobile by 1985).

27. *Id.*

28. Intelligent Vehicle-Highway Systems Act of 1991, Pub. L. No. 102-240, 105 Stat. 2189, 2189–94.

29. *Id.*

30. Overview, DEF. ADVANCED RES. PROJECTS AGENCY, <http://archive.darpa.mil/grandchallenge/overview.html> (last visited Feb. 19, 2015).

31. See *id.* (“The Urban Challenge teams come from across the United States and around the world, and share a passion for the advancement of robotic technology and machine intelligence. This diverse group includes teams from both academia and the robotics, automotive, and defense industries.”).

32. E.g., Bilger, *supra* note 7.

or connected cars, all imply the idea that the car is digesting data from the environment and taking over a great share of the driving.

III. DEFINING THE SELF-DRIVING CAR

Aside from the DARPA grants, much of the federal government's involvement in the industry has been about safety. As of May 2013, the NHTSA has defined five levels of automation for the auto industry.³³ These levels are summarized in Table 1.

Table 1. NHTSA Levels of Automation³⁴

	Level 0	Level 1	Level 2	Level 3	Level 4
Name	"No Automation"	"Function-Specific"	"Combined Function"	"Limited Self-Driving"	"Full Self-Driving"
Control	Driver is in complete control at all times.	One or more control function is automated.	At least two primary control functions are automated and work in unison to relieve driver of control in certain situations.	Driver can cede full control of all safety-critical functions under certain conditions.	Vehicle performs all safety-critical driving functions.
Operation	Driver is solely responsible for safe operation and monitoring the roadway.	Driver is solely responsible for safe operation and monitoring the roadway, but can cede primary control or be assisted in certain situations.	Driver is responsible for safe operation and monitoring the roadway and is expected to be available to take control on short notice.	Driver can rely heavily on vehicle to monitor for changes in the roadway that require driver control. Driver is expected to be available for occasional control.	Vehicle monitors the roadway conditions for an entire trip.

33. NHTSA PRELIMINARY STATEMENT, *supra* note 16, at 4–6.

34. Data for Table 1 is derived from *id.* at 4–5.

IV. TECHNOLOGICAL DEVELOPMENT

The majority of SDV technologies under development focus on the car as the self-contained primary technology and not on external infrastructure.³⁵ While the vehicle might gather information from the cars surrounding it in a “connected” manner, the technology to self-drive is under development to come almost entirely from within (or on) the car.³⁶ While the focus appears to be on self-contained vehicles, it is likely that the complete SDV will include some vehicle-to-vehicle communication (V2V) and some vehicle-to-infrastructure communication (V2I). Examples of V2V might include vehicles that set speed or traveling distance based on information from surrounding vehicles,³⁷ and examples of V2I might include interaction with traffic lights to manage road congestion.³⁸ In February 2014, NHTSA stated that it would focus on the development of V2V communication to allow for the deployment of safety technologies that help drivers monitor other cars to prevent crashes.³⁹ The discussion around enhanced roads lags behind that of enhanced vehicles, due to cost and scalability.⁴⁰ From a cost perspective, the ability to attach or incorporate an apparatus into an existing vehicle that can be utilized wherever the vehicle travels beats the necessary dual technologies that would be needed within the car and on the road for a system that relies on enhanced roads.⁴¹ Additionally, while road and infrastructure development in the United States depend on federal, state, and sometimes local

35. FAGNANT & KOCKELMAN, *supra* note 7, at 1–2.

36. *See also* KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 10–15 (presenting the benefits of converging “connected-vehicle communication” technology with primary self-contained technology).

37. Press Release, Nat’l Highway Traffic Safety Admin., U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles (Feb. 3, 2014), *available at* <http://www.nhtsa.gov/About+NHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles>.

38. FAGNANT & KOCKELMAN, *supra* note 7, at 6.

39. Press Release, Nat’l Highway Traffic Safety Admin., *supra* note 37.

40. Bilger, *supra* note 7.

41. *See generally* FAGNANT & KOCKELMAN, *supra* note 7, at 10–11 (“As AVs migrate . . . to mass-produced designs, it is possible that these costs could fall somewhere close to . . . [the] \$3,000 mark, and eventually just \$1,000 to \$1,500 more per vehicle.”); LITMAN, *supra* note 17, at 4–5 (stating that estimated future costs “are likely to become cheaper with mass production”).

cooperation and involvement in construction, vehicle enhancements can be developed independently by manufacturers and subjected to more limited regulation.⁴²

Focusing on the vehicle, a number of technological enhancements combine to make the SDV possible.

A. CURRENT VEHICLE ADAPTATIONS

Consumers are being prepared to adopt self-driving technology. The current autonomous enhancements incorporated into modern vehicles provide a window into where development is headed. Technologies rely on sensors within the car for operation.⁴³ Assist technologies include GPS, park assist, and adaptive cruise control.⁴⁴ Crash avoidance technologies include back-up cameras and warnings, lane departure warnings, and blind spot detectors.⁴⁵ Many of these advancements now come standard in new model vehicles, especially luxury brands.⁴⁶

B. OTHER SENSORS

The next area of sensor-based technology provides greater breadth and depth of information to the vehicle about the surrounding environment.⁴⁷ This will allow the vehicle to perform more functions for the driver. Google's car relies on Light Detection and Ranging (LIDAR) to provide a picture of the area around the car.⁴⁸ Other manufacturers use a combination of less powerful sensors and cameras to provide data needed for self-driving.⁴⁹

42. See also Bryant Walker Smith, *Automated Vehicles Are Probably Legal in the United States*, 1 TEX. A&M L. REV. 411, 412–13 (2014) (stating that autonomous vehicles may already be legal to sell and use on public roads under existing regulations); Bilger, *supra* note 7 (highlighting progress of numerous manufacturers in developing autonomous enhancements).

43. NHTSA PRELIMINARY STATEMENT, *supra* note 16, at 2–3.

44. FAGNANT & KOCKELMAN, *supra* note 7, at 1.

45. See *supra* notes 11–12 and accompanying text.

46. See *supra* note 12 and accompanying text.

47. KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 10–12.

48. *Id.* at 12.

49. See Bilger, *supra* note 7 (“Along with Nissan, Toyota and Mercedes are probably closest to developing systems like Google’s.”).

C. V2V AND V2I COMMUNICATION

The most advanced enhancement is Dedicated Short-Range Communication (DSRC), which operates on a short range wireless system.⁵⁰ Notably, only vehicles with this technology can communicate with each other.⁵¹ While NHTSA sees in-vehicle crash avoidance systems like dynamic brake assistance and V2V communication as separate streams of development,⁵² they have placed them along a continuum, indicating that these technologies can be additive and converge in the self-driving vehicle.⁵³

V. CURRENT EVENTS

This table summarizes the 2013/2014 status of the various SDV projects and how the technology is currently being brought to market.

Table 2. Current Events

Company	Product	Developments	Public Statements
Audi	“Piloted Driving” ⁵⁴	1) Research with Volkswagen Group Electronics Research Lab and Stanford University ⁵⁵ 2) 2010 Autonomous Audi TTS Pikes Peak Research Car ⁵⁶ 3) Smaller laser sensor (about the size of a fist) ⁵⁷ 4) Received the third license to test in Nevada in 2013 ⁵⁸	At the 2013 Consumer Electronics Show: “Today, Audi defines autonomous driving capabilities in terms of piloted parking and piloted driving.” ⁵⁹

50. KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 12.

51. *Id.* at 13.

52. NHTSA PRELIMINARY STATEMENT, *supra* note 16, at 3.

53. *See generally* KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 10–15 (explaining the need for the “convergence of sensor-based technologies and connected-vehicle communications”).

54. *Id.*

55. *Piloted to the Peak: Audi TTS Pikes Peak*, AUDI, http://www.audi.com/com/brand/en/vorsprung_durch_technik/content/2014/10/pikes-peak.html (last visited Feb. 21, 2015).

56. *Id.*

57. Heather Kelly, *Driverless Car Tech Gets Serious at CES*, CNN (Apr. 7, 2014, 8:53 AM), <http://www.cnn.com/2014/01/09/tech/innovation/self-driving-cars-ces/>.

58. Hannah Elliot, *Audi Follows Google’s Lead, Gets Pass for Driverless Cars*, FORBES (Jan. 7, 2013, 11:29 AM), <http://www.forbes.com/sites/hannahelliott/2013/01/07/audi-follows-googles-lead-gets-pass-for-driverless-cars/>.

BMW	"Electronic co-pilot system" ⁶⁰	1) Partnership with automotive supplier Continental 2013–2014 2) 2011 research prototype with 10,000+ driverless kilometers 3) BMW Track Trainer—"digital map, GPS, video data" to navigate racing circuit autonomously ⁶¹	BMW Europe Press Release 2013: "The main goal of the research partnership is to have highly automated driving functions ready for implementation until 2020 and thereafter." ⁶²
Ford	"Automated Fusion Hybrid" ⁶³	1) Automated Fusion Hybrid is a research platform for future fully automated vehicles 2) "Blueprint for Mobility," which envisions a future of autonomous functionality and advanced technologies after 2025 3) Partnership with University of Michigan and State Farm ⁶⁴	Automated Fusion Hybrid Press Release, December 2013: "We see a future of connected cars that communicate with each other and the world around them to make driving safer, ease traffic congestion and sustain the environment." ⁶⁵
General Motors	"Super Cruise" ⁶⁶ "Chevy EN-V" ⁶⁷	1) GM-Carnegie Mellon University Autonomous Driving Collaborative Research Lab—partnership won DARPA in 2007 ⁶⁸	GM Innovation: Design & Technology: "In fact, we expect semi-autonomous vehicles to be available to customers before the end of this decade and the

59. Michael Harley, *Nevada Grants Audi Third License to Operate Autonomous Vehicles*, AUTO BLOG (Jan. 8, 2013, 11:15 AM), <http://www.autoblog.com/2013/01/08/nevada-grants-audi-third-license-to-operate-autonomous-vehicles/>.

60. Press Release, BMW Grp., *Heading for Europe's Motorways in a Highly Automated BMW: BMW Group and Continental Team Up on Next Step Towards Highly Automated Driving* (Feb. 26, 2013), *available at* <https://www.press.bmwgroup.com/global/pressDetail.html?title=heading-for-europe-s-motorways-in-a-highly-automated-bmw-bmw-group-and-continental-team-up-on-next&outputChannelId=6&id=T0137270EN>.

61. *Id.*

62. *Id.*

63. *Ford Reveals Automated Fusion Hybrid Research Vehicle*, FORD (Dec. 12, 2013, 1:30 PM), <http://www.at.ford.com/news/cn/Pages/Automated.aspx>.

64. *Id.*

65. *Id.*

66. *'Super Cruise' Takes on Real-World Traffic Scenarios: Cadillac's Semi-Automated Vehicle Technology Undergoes Further Testing*, GEN. MOTORS (Apr. 29, 2013), <http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2013/Apr/0429-cadillac-super-cruise.html>.

67. *Emerging Technology: Driving Safety, Efficiency and Independence*, GEN. MOTORS, http://www.gm.com/vision/design_technology/emerging_technology.html (last visited Feb. 21, 2015).

68. Press Release, Carnegie Mellon Univ., General Motors, Carnegie Mellon Commit to Develop Driverless Vehicles (June 19, 2008), *available at* http://www.cmu.edu/news/archive/2008/June/june19_gmautonomousdriving.shtml.

		2) Super Cruise in Cadillac semi-automated driving system ⁶⁹ 3) Chevy EN-V autonomous, electric vehicle combines GPS with vehicle-to-vehicle communications and distance-sensing technologies to enable autonomous driving ⁷⁰	technology for fully autonomous vehicles capable of navigating the roadways ready during the next decade.” ⁷¹ Super Cruise Press Release, April 2013: “Super Cruise is designed to give the driver the ability of hands-free driving when the system determines it is safe to do so.” ⁷²
Lexus	“Advanced Active Safety Research Vehicle” ⁷³	1) Research Vehicle, Lexus LS460 with LIDAR ⁷⁴	At the 2013 Consumer Electronics Show: “Our goal is a system that constantly perceives, processes and responds to its surroundings.” ⁷⁵ “[A] driverless car is just part of the story for Toyota and Lexus. Our vision is a car equipped with an intelligent, always-attentive co-pilot whose skills contribute to safer driving.” ⁷⁶
Mercedes-Benz	“Mercedes-Benz Intelligent Drive” ⁷⁷	1) Intelligent Drive autonomous features use GPS technology and rear-facing camera with a pre-programmed route 2) Intelligent Drive has completed a 100 kilometer drive on real roads in Germany ⁷⁸	“Our approach is, let’s not do it with a special car with a lot of antennas, let’s do it with a standard car.” ⁷⁹

69. ‘Super Cruise’ Takes on Real-World Traffic Scenarios: Cadillac’s Semi-Automated Vehicle Technology Undergoes Further Testing, *supra* note 66.

70. *Emerging Technology: Driving Safety, Efficiency and Independence*, *supra* note 67.

71. *Id.*

72. ‘Super Cruise’ Takes on Real-World Traffic Scenarios: Cadillac’s Semi-Automated Vehicle Technology Undergoes Further Testing, *supra* note 66.

73. Press Release, Lexus, 2013 Consumer Electronics Show – Toyota Motor Corp. and Lexus Advance Active Safety Research Vehicle (Jan. 7, 2013), available at <http://pressroom.lexus.com/releases/2013+toyota+lexus+consumer+electronics+show+mark+templin+jan7.htm>.

74. *Safety Research Vehicle: A Glimpse Into the Future*, TOYOTA ESQ COMM. (Jan. 23, 2013), <http://www.toyota.com/esq/safety/r-and-d/safety-research-vehicle.html>.

75. Press Release, Lexus, *supra* note 73.

76. *Safety Research Vehicle: A Glimpse Into the Future*, *supra* note 74.

77. *On the Way to Accident Free Driving*, MERCEDES-BENZ, <http://www.mercedes-benz-intelligent-drive.com/com/en/> (last visited Feb. 4, 2015).

78. Joseph Capparella, *Mercedes-Benz Debuts Autonomous Vehicle Technology*, AUTOMOBILE (Sept. 9, 2013), <http://www.automobilemag.com/features/news/mercedes-benz-debuts-autonomous-vehicle-technology-244655/>.

Nissan	"Autonomous Drive" ⁸⁰	1) Nissan 360: test drive of Nissan Leaf with "[l]aser scanners, Around View Monitor cameras, as well as advanced artificial intelligence and actuators." ⁸¹	"Nissan will be ready with revolutionary commercially-viable Autonomous Drive in multiple vehicles by the year 2020." ⁸²
Tesla	"Auto Pilot" ⁸³	1) Mid 2013: early development phase to introduce a lower cost sensor system ⁸⁴	"Intense effort under way at Tesla to develop a practical autopilot system for Model S" ⁸⁵ "We should be able to do 90 per cent of miles driven within three years." ⁸⁶
Volkswagen	"Temporary Auto Pilot" ⁸⁷	1) Partnership with Stanford and ERL ⁸⁸ 2) Demonstrated Temporary Auto Pilot system in 2011 ⁸⁹	"Volkswagen Electronics Research Laboratory, autonomous driving research is exploring the necessary systems and infrastructure to enable truly driverless vehicles." ⁹⁰

79. Matthew de Paula, *Autonomous Driving Tech Package Will Be an Option on Mercedes Vehicles by 2020*, FORBES (Sept. 20, 2013, 11:33 PM), <http://www.forbes.com/sites/matthewdepaula/2013/09/30/autonomous-driving-will-become-an-option-on-regular-mercedes-models-by-2020/>.

80. Press Release, Nissan, Nissan Announces Unprecedented Autonomous Drive Benchmarks (Aug. 27, 2013), *available at* <http://nissannews.com/en-US/nissan/usa/releases/nissan-announces-unprecedented-autonomous-drive-benchmarks>.

81. *Id.*

82. *Id.*

83. *Dual Motor Model S and Autopilot*, TESLA (Oct. 10, 2014), <http://www.teslamotors.com/blog/dual-motor-model-s-and-autopilot>.

84. *See also id.* ("Every single Model S now rolling out of the factory includes a forward radar, 12 long range ultrasonic sensors positioned to sense 16 feet around the car in every direction at all speeds . . .").

85. Elon Musk, TWITTER (Sept. 18, 2013), <https://twitter.com/elonmusk/status/380451200782462976>.

86. Richard Waters & Henry Foy, *Tesla Moves Ahead of Google in Race to Build Self-Driving Cars*, FIN. TIMES (Sept. 17, 2013, 6:56 PM), <http://www.ft.com/intl/cms/s/0/70d26288-1faf-11e3-8861-00144feab7de.html#axzz3R4wofCEw> (citing interview with Tesla CEO Elon Musk).

87. *Temporary Auto Pilot: (Semi-) Automatic Driving Is Safe Driving*, VOLKSWAGEN, http://www.volkswagenag.com/content/vwcorp/content/en/innovation/driver_assistance/Temporary_Auto_Pilot.html (last visited Feb. 13, 2015).

88. VOLKSWAGEN, EXPERIENCE D[R]IVERSITY: ANNUAL REPORT 2010, 44–45 (2011), *available at* http://www.volkswagenag.com/content/vwcorp/content/en/misc/pdf-dummies.bin.html/downloadfilelist/downloadfile/downloadfile_14/file/Y_2010_e.pdf.

89. *Temporary Auto Pilot: (Semi-) Automatic Driving Is Safe Driving*, *supra* note 87.

90. *Innovation*, VOLKSWAGEN GROUP AM., <http://www.volkswagengroupamerica.com/technology.html> (last visited Feb. 21, 2015).

Volvo	“Drive Me” ⁹¹	1) “Drive Me’ public pilot project – partnership with Volvo Car Group and Swedish Transport Administration to pinpoint benefits of autonomous driving” by using 100 test cars ⁹²	
Google	“Self-Driving Car Project” ⁹³	1) Driven 500,000+ miles ⁹⁴ 2) Prototypes in operation using retrofitted LIDAR (Lexus and Prius models) ⁹⁵ 3) Developing own prototypes without steering wheels, brake or accelerator pedals ⁹⁶	Many, including a blog post by Chris Urmson, the Director of Google’s Self-Driving Car Project. ⁹⁷
Bosch	“Autonomous Vehicle” ⁹⁸	1) Provides technology for driver assistance functions like adaptive cruise control and high performance assistance systems ⁹⁹ 2) Partner with Stanford Center for Automotive Research and Stanford Law School ¹⁰⁰	FT interview: “Driver assistance functions will require many more electronics and sensors in the car. Suppliers are better able [than carmakers] to build the necessary economics of scale.” ¹⁰¹

91. Press Release, Volvo Car Grp., Volvo Car Group Initiates World Unique Swedish Pilot Project with Self-Driving Cars on Public Roads (Dec. 2, 2013), *available at* <https://www.media.volvocars.com/global/en-gb/media/pressreleases/136182/volvo-car-group-initiates-world-unique-swedish-pilot-project-with-self-driving-cars-on-public-roads>.

92. *Id.*

93. Urmson, *supra* note 1.

94. JAMES M. ANDERSON ET AL., RAND CORP., AUTONOMOUS VEHICLE TECHNOLOGY: A GUIDE FOR POLICYMAKERS 58 (2014), *available at* http://www.rand.org/content/dam/rand/pubs/research_reports/RR400/RR443-1/RAND_RR443-1.pdf.

95. See Bilger, *supra* note 7.

96. Urmson, *supra* note 1.

97. *E.g., id.*

98. *Autonomous Technologies and Robotics*, BOSCH, <http://www.bosch.us/content/language1/html/9713.htm> (last visited Feb. 13, 2015).

99. Press Release, Bosch, Vision Zero: Safety and Driver Assistance Systems Contribute to Future Automated Driving (Apr. 4, 2014), *available at* http://auto2014.bosch.com.cn/web/site_en/technology_press02.html.

100. *Autonomous Technologies and Robotics*, *supra* note 98.

101. Chris Bryant, *Bosch Wants Piece of Self-Drive Car Market*, FIN. TIMES (Nov. 14, 2013, 1:56 PM), <http://www.ft.com/intl/cms/s/0/ae1ebda2-46cf-11e3-9c1b-001444feabdc0.html#axzz3QqSR4tk8> (interviewing Volkmar Denner, Bosch CEO).

VI. IMPLICATIONS

A. SAFETY

By far the greatest implication referenced by those in the field is related to safety and convenience.¹⁰² Individuals, car manufacturers, and governments have always been concerned about safety. It is not surprising that the chance to improve safety is one of the most popular propositions for SDVs.¹⁰³ While many of the convenience benefits of SDVs are somewhat intangible and accrue to the user, safety benefits can be referenced in number of lives saved and accidents prevented and accrue to other roadway users—drivers, pedestrians, and society as a whole.

NHTSA's 2008 Crash Causation Survey found that close to ninety percent of crashes are caused by driver mistakes.¹⁰⁴ These mistakes, which include distractions, excessive speed, disobedience of traffic rules or norms, and misjudgment of road conditions, are factors within control of the driver.¹⁰⁵ Volvo refers to these driver mistakes as “the 4Ds: distraction, drowsiness, drunkenness, and driver error.”¹⁰⁶ The leading perspective is that because SDVs would not be vulnerable to these weaknesses, they could reduce or eliminate human error in the driving process and work towards preventing the annual 1.24 million deaths globally¹⁰⁷ and 34,000 deaths in the United States from car accidents.¹⁰⁸ Few attempts have been made to analyze the value to individuals and society from accident reduction due to SDVs. One estimate from the Eno Center for Transportation Studies, a D.C.-based industry research group, put cost savings “in the range of \$25 billion” to over \$450

102. *E.g.*, FAGNANT & KOCKELMAN, *supra* note 7, at 3–4; NHTSA PRELIMINARY STATEMENT, *supra* note 16, at 1–3, 10.

103. *E.g.*, NHTSA PRELIMINARY STATEMENT, *supra* note 16, at 1–3.

104. *See* KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 7. *See generally* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., U.S. DEPT OF TRANSP., NATIONAL MOTOR VEHICLE CRASH CAUSATION SURVEY: REPORT TO CONGRESS 271 (2008) [hereinafter CRASH CAUSATION SURVEY], *available at* <http://www-nrd.nhtsa.dot.gov/Pubs/811059.PDF>.

105. *See* CRASH CAUSATION SURVEY, *supra* note 104, at 2–3.

106. Bilger, *supra* note 7.

107. WORLD HEALTH ORG., GLOBAL STATUS REPORT ON ROAD SAFETY 2013: SUPPORTING A DECADE OF ACTION 1, 227 (2013), *available at* http://www.who.int/iris/bitstream/10665/78256/1/9789241564564_eng.pdf.

108. *Id.* at 227.

billion, depending largely on the percentage of the population adopting the technology.¹⁰⁹ Other key assumptions contained in this and other analyses include the level of in-car automation reached, the cost of these technologies, capacity benefit (parking and congestion), injury and crash cost savings, and fuel savings.¹¹⁰

The opportunity for increased safety in SDVs is a good and probable one, and car manufacturers have often relied on safety features to promote sales of their vehicles.¹¹¹ The story for human drivers is not all bad, though. As a former NHTSA official noted, humans are surprisingly good at driving and cause far fewer accidents than we would expect.¹¹² The bar has been set particularly high for SDVs given the amount of decision making and reaction to changing circumstances that human drivers complete.¹¹³ Drivers have to recognize and classify objects (i.e., moving car versus stationary car), resolve conflicting messages (i.e., green light, but yield to a pedestrian), complete the mechanics of driving in various conditions (i.e., pumping brakes on ice), and conduct trip planning on a real time basis (i.e., road closure rerouting).¹¹⁴ To make it onto the roadways, SDVs must meet and surpass this standard. The millions of accidents that occur in the United States each year also represent millions that were likely prevented by split-second driver decisions.

While the consensus appears to be that SDVs will improve driving safety,¹¹⁵ several steps remain to realize these benefits. NHTSA has noted that how humans interact with SDV systems, such as responding to warning signals, and how well the systems mesh with a broad range of human thought processes, will be key factors.¹¹⁶ While NHTSA has issued statements on preliminary policy for automated driving vehicles,¹¹⁷ it appears to be staying out of the development of full SDVs and focusing on what it considers the “next

109. FAGNANT & KOCKELMAN, *supra* note 7, at 17.

110. *See, e.g., id.* at 18–20.

111. *See* ANDERSON ET AL., *supra* note 94, at 72–74; Bilger, *supra* note 7.

112. Bilger, *supra* note 7.

113. *Id.*

114. *See id.*

115. *See supra* note 102–03 and accompanying text.

116. *See* Statement of Hon. David L. Strickland, *supra* note 17, at 45–46.

117. *E.g.,* NHTSA PRELIMINARY STATEMENT, *supra* note 16.

generation of auto safety improvements.”¹¹⁸ As noted above, NHTSA has indicated that it will focus on V2V in the short term given its possible impact on safety.¹¹⁹ V2V certainly has safety implications. However, full SDVs are expected to do more than assist the driver; therefore, SDVs may have a greater impact on safety improvements.

B. CAPACITY

Capacity improvements are the next most often mentioned benefit from those in the field.¹²⁰ Roadway capacity improvement often means improvements in throughput, the maximum number of cars per hour per lane on a roadway, but can extend to other capacity concerns. Other hypothesized improvements include fewer lanes needed due to increased throughput, narrower lanes because of accuracy and driving control of SDVs, and a reduction in infrastructure wear and tear through fewer crashes.¹²¹ The theory is cars that can communicate with one another can follow each other at a much reduced distance, maintain and adjust speed more efficiently, change lanes and merge into traffic more effectively, and even benefit from drafting other vehicles.¹²² In the area of traffic management, Dresner and Stone of the University of Texas at Austin note that SDVs could allow for changes in intersection use.¹²³ They model a “reservation based” approach to intersection management enabled by SDV and infrastructure technology rather than a system of stoplights.¹²⁴ Increases in capacity ultimately mean more convenient travel and reductions in congestion, which currently costs Americans \$100 billion in wasted fuel and lost time, according to some reports.¹²⁵

118. See Press Release, Nat’l Highway Traffic Safety Admin., *supra* note 37.

119. *Id.*

120. See, e.g., FAGNANT & KOCKELMAN, *supra* note 7, at 1, 4–5.

121. ANDERSON ET AL., *supra* note 94, at 17, 21–24; KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 26.

122. FAGNANT & KOCKELMAN, *supra* note 7, at 4–5, 20.

123. Kurt Dresner & Peter Stone, *A Multiagent Approach to Autonomous Intersection Management*, 31 J. ARTIFICIAL INTELLIGENCE RES. 591, 591–96 (2008).

124. *Id.* at 596–97.

125. E.g., KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 29.

C. MOBILITY AND ACCESS

Access to car transportation is currently limited to those who own a vehicle and can physically drive or those who can find someone to drive for them. While supplemental transportation programs and senior shuttles have provided needed services in recent decades, SDVs have the ability to expand the user base of cars to those who would normally be unable to physically drive.¹²⁶ The elderly, disabled, and even children may be beneficiaries.¹²⁷ Benefits might include increased independence and reduced cost of travel for those new users.¹²⁸ Expansion of the user base would not just mean increased mobility for new users, but also flexibility for those who previously acted as drivers. Drop offs at the airport or the mall might become a thing of the past, and with these changes would come more time to be productive, active, or restful.

D. VEHICLE DIVERSITY

The question of whether SDVs would look like the cars of today remains open. For example, Personal Rapid Transit cars, autonomous vehicles that use some infrastructure modification to navigate city streets, which are already in operation in Masdar City, Abu Dhabi, look more pod-like than car-like.¹²⁹ At the highest levels of automation, a steering wheel may no longer be necessary,¹³⁰ freeing up valuable space to be redesigned. Further, if safety benefits at the highest level are achieved, existing safety features such as airbags may be unnecessary, changing the space needs of the modern automobile.¹³¹ Additionally, the types of material like steel and aluminum cages and frames may change if the nature of automobile accidents changes. Narrow and specialized cars would potentially be more feasible in this case. Vehicle type could also change with the advent of SDVs. For decades, car manufacturers have marketed and sold cars based on factors

126. ANDERSON ET AL., *supra* note 94, at 16–17; FAGNANT & KOCKELMAN, *supra* note 7, at 1, 6.

127. ANDERSON ET AL., *supra* note 94, at 16–17.

128. *Id.*

129. See Masdar, ADVANCED TRANSIT ASS'N, <http://www.advancedtransit.org/advanced-transit/applications/masdar-prt/> (last visited Feb. 23, 2015).

130. As discussed above, Google has produced a prototype without a steering wheel. See *supra* note 1 and accompanying text.

131. See KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 31.

like handling, control, and ultimately the connection between car and driver.¹³² With that connection unnecessary, the kinds of vehicles demanded by consumers may change.

Lastly, certain types of vehicles could be eliminated from our roadways, such as taxis.¹³³ Mass transportation vehicles and freight transit could change in type of function in response to SDVs, or could incorporate SDV technology.¹³⁴

E. COST OF OWNERSHIP

The cost of car ownership is currently calculated on the basis of six costs: depreciation, fuel, interest, insurance, maintenance and repair, and sales tax.¹³⁵ SDVs will likely affect the costs in each of these areas in different ways. The potential ownership cost implications for SDVs are varied, but can broadly be grouped into those related to changes in the ownership model for vehicles and changes in the operating costs of owning a car.

1. Ownership Model

The current car ownership model focuses on individual or family ownership. Based on United States DOT data, this amounts to more than one car per household.¹³⁶ People own cars to get them to and from work and school and everywhere in between on their own schedule. However, cars often sit idle for many hours of the day in parking lots and garages, on side streets, and in driveways. With the SDV's ability to direct itself to different locations, those idle hours could become useful to

132. See KPMG, SELF-DRIVING CARS: ARE WE READY? 4, 26 (2013), available at <https://www.kpmg.com/US/en/IssuesAndInsights/ArticlesPublications/Documents/self-driving-cars-are-we-ready.pdf>.

133. See FAGNANT & KOCKELMAN, *supra* note 7, at 9.

134. *Id.* at 7–9.

135. *What That Car Really Costs to Own*, CONSUMER REP., <http://consumerreports.org/cro/2012/12/what-that-car-really-costs-to-own/index.htm> (last updated Aug. 2012).

136. See DAPHNE LOFQUIST ET AL., U.S. CENSUS BUREAU, C2010BR-14, HOUSEHOLDS AND FAMILIES: 2010 2 (2012), available at <http://www.census.gov/prod/cen2010/briefs/c2010br-14.pdf> (counting 116,716,292 total households in 2010); Bureau of Trans. Statistics, *Table 1-11: Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances*, U.S. DEPARTMENT TRANSP., http://www.rita.dot.gov/bts/sites/rita.dot.gov/bts/files/publications/national_transportation_statistics/html/table_01_11.html (last visited Feb. 23, 2015) (counting 253,639,386 registered highway vehicles in 2012).

others.¹³⁷ These others might be within the family, reducing the number of cars per household, or others in a community that communally own a vehicle.¹³⁸ Car sharing services in the late 2000s and early 2010s have already demonstrated the market for communal vehicles;¹³⁹ transferring the concept to SDVs hardly seems a stretch. There are several forms ownership could take: private entities that rent per mile, car sharing co-ops, or publicly-owned fleets; but the potential to reduce the use of owner-operated vehicles is still remarkable. SDVs could provide a way to use the idle hours. If the SDV is not owned by an individual or family, then costs of ownership such as depreciation, car loan interest, and sales tax would obviously not be accrued by them and would be shifted to the entity owning the vehicle.¹⁴⁰ It is unclear whether any of these costs would change, however, given that depreciation is in part affected by the appeal and durability of the model.¹⁴¹ It is possible that SDVs could depreciate at a slower rate because of their desirability, the reduction in crashes, and reduced wear and tear associated with their use.

2. Operating Costs

SDVs could also have important implications for the operating costs of vehicles. Most notably, car repairs and maintenance costs may go down as a result of fewer accidents and more appropriate and efficient vehicle operation. Safer vehicles and a safer U.S. fleet overall could put downward pressure on insurance prices if policies continue to be bought and sold as they are now.¹⁴² Lastly, a few in the field have made connections between more efficient driving habits and

137. See FAGNANT & KOCKELMAN, *supra* note 7, at 7.

138. See, e.g., ANDERSON ET AL., *supra* note 94, at 18–20; FAGNANT & KOCKELMAN, *supra* note 7, at 7; KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 28.

139. See, e.g., *Zipcar Overview*, ZIPCAR, <http://www.zipcar.com/press/overview> (last visited Feb. 23, 2015).

140. See ANDERSON ET AL., *supra* note 94, at 19–20.

141. See NADA, VOLATILITY IN USED VEHICLE DEPRECIATION: HISTORICAL TRENDS & FUTURE OUTLOOK 2–5 (2012), available at http://www.nada.com/b2b/Portals/0/assets/pdf/NADA_WhitePaper_VolatilityInUsedVehicleDepreciation.pdf (observing that used vehicle depreciation can vary widely based on external factors like new vehicle supply and availability of late-model used vehicles).

142. See ANDERSON ET AL., *supra* note 94, at 112–18.

fuel savings.¹⁴³ Simply driving the speed limit and drafting other vehicles, as SDVs could potentially do, could result in fuel cost savings.¹⁴⁴ In addition, to the extent that SDVs result in lighter vehicles, baseline miles per gallon could increase as well.¹⁴⁵

F. TRAVEL BEHAVIOR

Second order implications of SDVs could include individual changes in destinations and journey behavior. As noted above, the costs associated with car ownership could change dramatically, and the availability of car travel could expand to new groups.¹⁴⁶ These changes affect the real and perceived cost of travel. With less effort required to execute a trip, individuals may choose to take more trips.¹⁴⁷ Todd Litman of the Victoria Transportation Institute has reviewed the literature on transport elasticity values, how changes in cost elements of the driving experience affect vehicle ownership or transport behavior.¹⁴⁸ Overall increases in operating expenses decrease vehicle use,¹⁴⁹ so reductions in operating costs by SDVs would seem to indicate an increase in vehicle use and travel. Of particular note is that greater parking fees reduce the amount of vehicle travel and “increased travel speed” or “reduced delay . . . tends to increase travel distance.”¹⁵⁰ If SDVs reduce the need for parking, as discussed next, there could be an increase in trips taken. Other second-order implications could involve the places people choose to live. In recent decades, the worldwide movement of individuals has been from rural areas to urban centers.¹⁵¹ While this trend is expected to continue,¹⁵²

143. *E.g., id.* at 28–30.

144. *See id.*

145. *Id.* at 28–33; KPMG & CTR. FOR AUTO. RESEARCH, *supra* note 3, at 31.

146. *See supra* text accompanying notes 126–128, 135–145.

147. *See* ANDERSON ET AL., *supra* note 94, at 16–18; FAGNANT & KOCKELMAN, *supra* note 7, at 6–7.

148. *See* TODD LITMAN, VICTORIA TRANSP. POLICY INST., UNDERSTANDING TRANSPORT DEMANDS AND ELASTICITIES: HOW PRICES AND OTHER FACTORS AFFECT TRAVEL BEHAVIOR 1–5 (2013), *available at* <http://www.vtpi.org/elasticities.pdf>.

149. *Id.* at 31.

150. *Id.* at 43–46.

151. *Urban Population Growth*, WORLD HEALTH ORG., http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/ (last visited Mar. 1, 2015).

the decreased travel costs in time and energy allowed by SDVs could result in people living further from urban centers and, in the most extreme cases, could create urban sprawl.¹⁵³ However, the change in ownership model may have an opposite effect. Currently, most of the vehicle ownership costs are fixed (purchase, insurance, license, etc.), which creates an incentive to drive more (i.e., costs per mile go down as miles driven go up).¹⁵⁴ If the ownership model changed into that of a fleet, then most of the trip cost becomes variable and visible.¹⁵⁵ According to the IRS, the current cost of car ownership is 56.5 cents per business mile.¹⁵⁶ This may have a downward impact on vehicle miles traveled (VMT). Lastly, SDVs could be programmed to adhere to traffic rules, resulting in perhaps a much more desirable change, that of fewer driving violations and more compliant travel behavior.

G. LAND USE, PARKING, AND CITY PLANNING

Volvo recently released a video on the potential for SDVs over the next few decades.¹⁵⁷ One of the main selling points remains the increased productivity during commuting time.¹⁵⁸ Changing commuting time to productive or even restful time in a vehicle could result in less pressure for workers to live near the city center. Clearly urban sprawl or a decreased need to live close to urban centers will impact city and regional planning. Commuter trains and rapid bus routes have enabled

152. *Id.*

153. See ANDERSON ET AL., *supra* note 94, at 5, 39.

154. TODD LITMAN, VICTORIA TRANSP. POLICY INST., TRANSPORTATION COST AND BENEFIT ANALYSIS: TECHNIQUES, ESTIMATES, AND IMPLICATIONS 5.1-11 (2009), available at <http://www.vtpi.org/tca/tca0501.pdf>; see Victoria Transp. Policy Inst., *Win-Win Transportation Solutions: Cost-Effective, Market-Based Strategies to Encourage Efficient Transport*, TDM ENCYCLOPEDIA, <http://www.vtpi.org/tdm/tdm52.htm> (last updated Aug. 31, 2014).

155. See ANDERSON ET AL., *supra* note 94, at 19.

156. See also *Standard Mileage Rates for 2013*, INTERNAL REVENUE SERVICE (Nov. 21, 2012), <http://www.irs.gov/uac/Newsroom/2013-Standard-Mileage-Rates-Up-1-Cent-per-Mile-for-Business,-Medical-and-Moving> (providing the standard mileage rate, based on the costs of car ownership, allowed by the IRS to be claimed as a deductible).

157. *Drive Me – Self-Driving Cars for Sustainable Mobility*, VOLVO CAR GROUP (Dec. 2, 2013), <https://www.media.volvocars.com/global/en-gb/media/videos/136297/drive-me-self-driving-cars-for-sustainable-mobility>.

158. See Press Release, Volvo Car Grp., *supra* note 91.

exurban living for some time and SDVs have the potential to do the same. The extent to which this technology might affect trends towards urbanization remains to be seen, but the length of commuting distances could increase.

On the other hand, several reports and studies note the percentage of time that vehicles spend parked and the percentage of urban landscapes taken up by parking spaces, lots, and ramps.¹⁵⁹ If SDVs can use the idle time or park themselves away from city centers, there might be less need for parking spaces in urban areas. An increase in available space due to a reduction in parking could free up space for other purposes, like housing or commerce. In this case, SDVs would combat urban sprawl and provide more useful land for living spaces.

H. TECHNOLOGY COST

Most of our discussion on implications has focused on public and private benefits due to SDVs, but embedded therein are public and private costs as well. SDVs are an expensive technology at current rates.¹⁶⁰ LIDAR and related vehicle adaptations would cost in the tens of thousands for each car today.¹⁶¹ While developers and manufacturers expect the costs of technology to decrease rapidly, as it often does with mass production, the needed technology adaptations are still an added cost that will likely be reflected in the purchase price of such vehicles.¹⁶² Additionally, there is an ambiguous impact when capacity, mobility, and travel behavior implications are considered together. While existing roadways may support increased throughput with SDVs, the increased use from an expanded user base and reduced travel costs could eliminate the congestion benefits of this increased capacity. Another cost could be jobs eliminated, possibly including taxi drivers, parking attendants, valet parkers, car mechanics, meter attendants, traffic officers, and potentially bus and freight drivers.

159. See, e.g., ANDERSON ET AL., *supra* note 94, at 26–27.

160. E.g., FAGNANT & KOCKELMAN, *supra* note 7, at 10–11.

161. See *id.*

162. See Bilger, *supra* note 7; see, e.g., FAGNANT & KOCKELMAN, *supra* note 7, at 10–11.

VII. LEGAL AND POLICY ISSUES

SDVs will not only transform the way people travel and commute, but also have implications in the legal and policy arena. From state and national statutes to liability, privacy, and insurance rules, policymakers and rule makers will need to carefully consider and modify current law to accommodate contemporary issues.

A fair amount has been written and continues to be written on the legal context in which SDVs will operate, including one piece by an author of this work.¹⁶³ These questions can become complex as the current legal system can apparently accommodate SDVs, but will need additional clarity from lawmakers or courts to address many areas of uncertainty.

A. LEGALITY

There appears to be emerging agreement that SDVs are likely legal to operate in the United States, but most current state statutes do not fully address the specific challenges presented.¹⁶⁴ Law modification and regulatory action are likely necessary for the safety of SDV manufacturers, operators, and others on the road. Bryant Walker Smith of the Center for Internet and Society at Stanford Law School notes that state codes appear to assume the presence of a human driver at all times and the codes create laws defining specific items such as “following distance” with that in mind.¹⁶⁵

B. INSURANCE AND LIABILITY

A main area of inquiry is the anticipated impact of SDVs on legal liability and insurance policies. Will insurance cover SDV accidents? Will the operator, the owner, or the manufacturer be held liable? Liability rules applying to SDVs will need to define roles, determine fault, and fix compensation for harm, as current law does for non-automated vehicles. Automobile accident liability cases are most often decided on theories of negligence or strict liability, which include no-fault statutes employed by some states.¹⁶⁶ Negligence attempts to

163. *E.g.*, Frank Douma & Sarah Aue Palodichuk, *Criminal Liability Issues Created by Autonomous Vehicles*, 52 SANTA CLARA L. REV. 1157 (2012).

164. *E.g.*, Smith, *supra* note 42, at 412–13, 463.

165. *Id.* at 413, 518–21.

166. ANDERSON ET AL., *supra* note 94, at 112–14.

assign fault based on the specific conditions of the case and a series of criteria that define the relationship between the involved actors.¹⁶⁷ Strict liability assigns fault based primarily on the existence of a violation under the law.¹⁶⁸ However, in strict liability automobile accident cases, the courts have often employed some kind of reasonableness standard, which moves them more towards a negligence framework.¹⁶⁹ As such, it is likely that the legal framework under which SDVs will operate will be one of negligence. The theory of negligence is constructed from five elements: 1) duty of care, 2) breach of the duty of care, 3) cause of harm, 4) physical harm, and 5) proximate cause.¹⁷⁰ For SDVs, the main question under this framework appears to be who has the duty of care (responsibility) and what are the consequences of breaching that duty.¹⁷¹ Depending upon how these questions are answered by the courts or addressed by legislators, SDVs could take on a product liability bent where manufacturers are held liable, liability might be transferred to a corporate entity owning or providing SDVs for rent, or liability might be transferred to the operator or private owner at the time of the accident.¹⁷²

C. OPERATOR RESPONSIBILITY

These legal questions are sure to be influenced by the level of automation under consideration. For instance, in those levels where the driver remains substantially in control of the vehicle, it is less likely that new legal precedent will be created. Current precedent may even apply to levels of automation in which the driver receives warnings and is expected to take over if the SDV system needs to disengage, although it is questionable whether a human “fail safe” can be reasonably expected.¹⁷³ Full automation, however, creates the potential for

167. See Smith, *supra* note 42, at 591–94.

168. E.g., Douma & Palodichuk, *supra* note 163, at 1159.

169. See ANDERSON ET AL., *supra* note 94, at 120–23.

170. E.g., *Negligence*, LEGAL INFO. INST., <https://www.law.cornell.edu/wex/negligence> (last visited Mar. 1, 2015).

171. See, e.g., Robert W. Peterson, *New Technology—Old Law: Autonomous Vehicles and California’s Insurance Framework*, 52 SANTA CLARA L. REV. 1341, 1352–62 (2012).

172. See *id.*

173. See Bilger, *supra* note 7.

operators who are not physically able to drive.¹⁷⁴ In those cases responsibility, negligence, and liability may be less clear.

D. DATA AND PRIVACY

A lot of data is generated in our twenty-first century interconnected, internet-enabled, media- and information-rich lives. A key business and policy consideration worldwide concerns “big data,” or very large data sets generated by the content and information shared by the use of technology in a broad range of industries.¹⁷⁵ SDVs will likely generate a great deal of data on operators’ travel habits, including information on GPS location, speed, traffic, weather conditions, and road conditions, as well as information about other road users around the operator. How to protect or use that data is an open question being debated.¹⁷⁶

Important context on privacy within vehicles was set by the 1983 Supreme Court decision in the case *United States v. Knotts*.¹⁷⁷ This case determined that those traveling on a public road have “no reasonable expectation of privacy” in their movement.¹⁷⁸ State laws may add privacy protection, but these rules differ by state and therefore provide a patchwork of protection across the United States.¹⁷⁹ SDVs bring a new element in their ability to collect, act upon, and store much more data than was the case for vehicles in 1983. Questions of use of data have often focused on the ability of law enforcement to use new types of data and whether a warrant is required.¹⁸⁰ Supreme Court cases in 2012 and 2014 have held that attaching a GPS tracking unit to a vehicle¹⁸¹ and searching a cell phone’s content¹⁸² require a warrant.

174. See *supra* notes 126–28 and accompanying text.

175. *Big Data and the Future of Privacy*, EPIC.ORG, <https://www.epic.org/privacy/big-data/#overview> (last visited Mar. 1, 2015).

176. See, e.g., ANDERSON ET AL., *supra* note 94, at 94–95.

177. See generally *United States v. Knotts*, 460 U.S. 276 (1983).

178. *Id.* at 281–82.

179. Dorothy Glancy, *At the Intersection of Visible and Invisible Worlds: United States Privacy Law and the Internet*, 16 SANTA CLARA COMPUTER & HIGH TECH. L.J. 357, 378 (2000).

180. See, e.g., Dorothy J. Glancy, *Privacy in Autonomous Vehicles*, 52 SANTA CLARA L. REV. 1171, 1219–25 (2012).

181. *United States v. Jones*, 132 S. Ct. 945, 948–49, 954 (2012).

182. *Riley v. California*, 134 S. Ct. 2473, 2485 (2014).

As policymakers consider how to include privacy protections for the data requirements of SDVs, they will need to weigh the costs of protection on manufacturers and business owners against the benefits to operators or individuals. Policymakers might consider avenues such as setting limits on secondary uses of SDV data or setting time limits for the retention of that data. Until policymakers act, industry means of privacy protection and information will be the default. A possible model could be the provision of privacy policies with opt-in mechanisms or information for consumers on how data will be gathered and used.

E. FEDERAL REGULATION

As mentioned above, NHTSA issued a 2013 policy statement outlining its definition of SDVs and related technology, its thoughts on the implications for highway safety, and recommendations for state policymakers.¹⁸³ The NHTSA recommended that state policymakers only issue rules governing testing within their respective states.¹⁸⁴ Considerations included in the policy statement are discussed below and broadly cover who should be considered a qualified operator, where vehicle testing should be permitted, and the essential features of a safe SDV.¹⁸⁵

1. “Ensure that the Driver Understands How to Operate a Self-Driving Vehicle Safely” through a driver licensing program.¹⁸⁶
2. “Ensure that On-road Testing of Self-driving Vehicles Minimizes Risks to Other Road Users.” This includes certifying that “the vehicle has already operated for a certain number of miles in self-driving mode without incident” prior to testing “the vehicle on public roads.”¹⁸⁷
3. “Limit Testing Operations to Roadway, Traffic and Environmental Conditions Suitable for the Capabilities of the Tested Self-Driving Vehicles.” We encourage states to

183. See *supra* text accompanying note 16.

184. NHTSA PRELIMINARY STATEMENT, *supra* note 16, at 10.

185. *Id.* at 11–14.

“consider appropriate limitations on the conditions in which a vehicle may be operated in self-driving mode.”¹⁸⁸

4. “Establish Reporting Requirements to Monitor the Performance of Self-Driving Technology during Testing.”¹⁸⁹

5. “Ensure that the Process for Transitioning from Self-Driving Mode to Driver Control is Safe, Simple and Timely.”¹⁹⁰

6. Ensure that test vehicles have the capability to detect, record, and inform the driver that the automated systems have malfunctioned.¹⁹¹

7. “Ensure that Installation and Operation of any Self-Driving Vehicle Technologies Does not Disable any Federally Required Safety Features or Systems.” Federal law prohibits “making inoperative any federally required safety system” and the “installation of self-driving technologies should not degrade the performance of any of those federally required systems or the overall safety of the vehicle.”¹⁹²

8. “Ensure that Self-Driving Vehicles Record Information about the Status of the Automated Control Technologies in the Event of a Crash or Loss of Vehicle Control.”¹⁹³

Additionally, NHTSA more recently issued a statement on the directions of its research and its focus in the vehicle automation field.¹⁹⁴ In this action, NHTSA may have wished to focus on short-term safety objectives, it may have wished to leave manufacturers and developers to focus on SDV technology, or it may not consider SDVs viable enough at the present time to warrant its efforts. No matter the objective,

186. *Id.* at 11.

187. *Id.* at 11–12.

188. *Id.* at 12.

189. *Id.*

190. *Id.* at 13.

191. *Id.*

192. *Id.* at 13–14.

193. *Id.* at 14.

194. *See supra* text accompanying notes 37–39.

time will tell if the correct determination was made in this policy decision.

F. STATES' ACTION

Several state legislatures and the District of Columbia have taken action to address SDVs specifically in their statutes.¹⁹⁵ Washington, D.C., Nevada, California, Florida, and Michigan now allow the operation of SDVs within the state or district for *testing* purposes.¹⁹⁶ As NHTSA recommended, these states are providing rules on who can operate these vehicles,¹⁹⁷ rules that might include considerations on manufacturer size and insurance requirements.

California, the state where Google is based, is taking the most comprehensive approach in its SDV regulatory activities. In September 2012, California passed Senate Bill 1298, which allowed the testing of SDVs on its highways.¹⁹⁸ The law addressed how the state would define autonomous vehicles, set broad rules for testing, and instructed state agencies to write further rules related to testing and SDV operation beyond testing.¹⁹⁹ The law requires a person, defined as an “operator,” be in the vehicle and ready to take over should the autonomous technology disengage.²⁰⁰ In California’s case, the Department of Motor Vehicles (DMV), rather than a transportation agency or safety agency, is the one writing regulations on testing SDVs in the state.²⁰¹ The California DMV can call on another agency with expertise, however.²⁰² To complete this task, the California DMV has been holding several public hearings for comment as well as holding workshops with manufacturers,

195. *E.g.*, ANDERSON ET AL., *supra* note 94, at 41.

196. *Id.* at 41–48.

197. NHTSA PRELIMINARY STATEMENT, *supra* note 16, at 10–11; *see* ANDERSON ET AL., *supra* note 94, at 44–52.

198. ANDERSON ET AL., *supra* note 94, at 46–47; Smith, *supra* note 42, at 507.

199. ANDERSON ET AL., *supra* note 94, at 46–47; Smith, *supra* note 42, at 507.

200. ANDERSON ET AL., *supra* note 94, at 46–47; Smith, *supra* note 42, at 507.

201. *See* Smith, *supra* note 42, at 507.

202. *See Autonomous Vehicles in California*, CAL. DEPARTMENT MOTOR VEHICLES, <http://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/bkgd> (last visited Mar. 1, 2015).

academics, and public advocates to inform its rulemaking.²⁰³ As of the beginning of 2014, the California DMV had issued proposed regulatory language on testing permits that would be required to test within the state.²⁰⁴ Rulemaking for activities beyond testing has not currently been addressed. However, given the size of California and its early lead in developing rulemaking, it is presumed that its experiences will be a model for ongoing state action.

VIII. MINNESOTA PERSPECTIVES

A. LEGACY OF TRANSPORTATION INNOVATION

Minnesota is known around the country for innovative transportation systems, including its use of HOT lanes rather than toll highways.²⁰⁵ As it relates to SDVs, the Minnesota Department of Transportation (MnDOT) has partnered with University of Minnesota researchers to attach driver assist technology to snow plows to study the benefits to snow removal.²⁰⁶ How might Minnesota be able to carry that reputation to SDVs? Other states like California have looked to address SDVs in their rulemaking by codifying rules that specifically address the testing and operation of SDVs.²⁰⁷ One clear option is to regulate testing within the state as NHTSA has suggested.²⁰⁸ Additionally, we will take a look at current Minnesota statutes that may need to be modified or changed to address SDVs. Our brainstorming also extends to local and agency activities and the unique conditions in Minnesota. For instance, the presence of snow and inclement weather

203. For a summary of these public meetings and workshops see *Previous Autonomous Vehicle Public Workshops*, CAL. DEPARTMENT MOTOR VEHICLES, https://www.dmv.ca.gov/portal/dmv/?1dmy&urile=wcm:path:/dmv_content_en/dmv/vr/autonomous/prevavwrkshp (last visited Mar. 1, 2015).

204. *Autonomous Vehicles in California: Adopted Regulations for Testing of Autonomous Vehicles by Manufacturers*, CAL. DEPARTMENT MOTOR VEHICLES, <http://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/testing> (last visited Mar. 1, 2015).

205. MINN. STAT. § 160.93 (2014); *Mn/PASS I-394 'HOT' Lanes*, MINN. DEPARTMENT TRANSP., http://www.dot.state.mn.us/guidestar/2006_2010/mnpass_i394_hot_lanes.html (last visited Mar. 1, 2015).

206. *Driver Assist System Pilot for Minnesota Snowplows*, ITS INST., <http://www.its.umn.edu/Research/ProjectDetail.html?id=2013038> (last modified Nov. 12, 2013).

207. See *supra* notes 196–204 and accompanying text.

208. See NHTSA PRELIMINARY STATEMENT, *supra* note 16, at 10.

conditions in Minnesota present a challenge to self-driving technology.²⁰⁹ Google has noted that their self-driving prototypes have trouble interpreting data in a number of road conditions, one of which is snow-covered roads.²¹⁰ SDVs operating in the state would likely have to address this issue for year-round, fully autonomous operation. Limited use during inclement weather could be an option much in the way that motorcycles are not typically in use during winter months, but limiting use during bad weather would reduce the scope and impact of potential safety benefits noted earlier.²¹¹ This issue could be addressed by future innovations of manufacturers. If Minnesota were to adopt statutes addressing testing within the state, it is possible that it could become a testing ground for innovations that seek to address inclement weather issues with SDVs.

B. EXISTING MINNESOTA STATUTES

An initial examination of Minnesota driving rules indicates that they will likely need to be modified to accommodate the operation of SDVs. Minnesota's driving rules are in Minnesota Statute section 169.18.²¹² It is clear that these statutes were created with the expectation and assumption of a human driver present at all times. As an example, Chapter 169, Section 011, Subdivision 24 states, "Driver' means every person who drives or is in actual physical control of a vehicle."²¹³ Section 13 of the same chapter goes on to define reckless and careless driving, which includes a person driving a vehicle with disregard for the safety and rights of others.²¹⁴ Whether this chapter would need to be modified, or new sections added to address SDVs, is a decision for policy officials. However, some determinations would likely need to be made for SDVs to be covered under these statutes.

209. See FAGNANT & KOCKELMAN, *supra* note 7, at 4.

210. See Chris Urmson, *The Self-Driving Car Logs More Miles on New Wheels*, GOOGLE (Aug. 7, 2012), <http://googleblog.blogspot.com/2012/08/the-self-driving-car-logs-more-miles-on.html> ("To provide the best experience we can, we'll need to master snow-covered roadways . . .").

211. See *supra* text accompanying notes 102–19.

212. MINN. STAT. § 169.18 (2014).

213. § 169.011 subdiv. 24.

214. See § 169.13.

Another key provision for SDVs is legal liability in the same section of Minnesota law. First, rules for liability for damage to highway and highway structures are addressed.²¹⁵ An excerpt is included below as another example of rules that assume a single driver or owner which may need to be modified to address SDVs.

169.88 DAMAGES; LIABILITY.

(b) When such driver is not the owner of such vehicle, object, or contrivance, but is so operating, driving, or moving the same with the express or implied permission of the owner, then the owner and driver shall be jointly and severally liable for any such damage.

(c) Any person who by willful acts or failure to exercise due care, damages any road, street, or highway or highway structure shall be liable for the amount thereof.

(d) Damages under this section may be recovered in a civil action brought by the authorities in control of such highway or highway structure.²¹⁶

Minnesota is a no-fault insurance state.²¹⁷ Enacted into law to mitigate the economic effects of automobile accidents and speed up claims processing, the Minnesota No-Fault Automobile Insurance Act was passed in 1974.²¹⁸ This statute allows for compensation of damages in automobile accidents by the insured's insurance company regardless of fault.²¹⁹ The presence of this statute certainly might make the resolution of claims involving SDVs less complex as the insurance market may price premiums based on the relative risk of SDVs (and other vehicles on the road) and insureds would receive compensation from their own insurer. However, two restrictions are worth noting that may affect SDVs. Insurers typically cap claims at some level within an insurance policy.²²⁰ In this case, above the cap, fault determination would matter. Additionally, the no-fault statute only extends to bodily injury and does not include property damage.²²¹ In this case fault determination would also matter. With that in mind, rules governing who has or shares fault in the case of SDVs

215. § 169.88.

216. *Id.*

217. §§ 65B.41–42.

218. §§ 65B.41–71.

219. § 65B.42.

220. *See* § 65B.49.

221. § 65B.44 subdiv. 8.

(manufacturer, operator, or owner) will be essential in adjudicating these cases.

C. OTHER POLICYMAKING

Other policy areas that might need to be addressed for SDVs include environmental regulations, transportation planning, and zoning. Minnesota does not currently have emissions rules for vehicles on its roadways so there are no implications for SDVs on that front.²²² Minnesota has set clean energy goals in the past to encourage the development and use of energy sources that are more renewable.²²³ To the extent that SDVs allow more effective use of fossil fuels, they could contribute to this goal.

Transportation planning and management are a key policy area related to SDVs and many of the benefits of this technology accrue in this area. State statutes governing the MnDOT cite goals that may align with the benefits of SDV use, such as minimizing fatalities and injuries, providing a “reasonable travel time for commuters,” maintaining infrastructure in good repair, promoting the use of low-emission vehicles, and reducing greenhouse gas emissions.²²⁴ Therefore, embracing SDVs may help MnDOT reach these goals. Additionally, planning for the development of SDV technology may be necessary. Currently, MnDOT plans highway improvements and investments as much as twenty to fifty years ahead.²²⁵ These planning efforts certainly cover the period in which we expect SDVs to be more widely adopted. Planning for the impact of these vehicles on increased capacity, at least initially, could allow MnDOT to more accurately predict transportation needs in the upcoming decades.

Lastly, one key implication noted earlier was in the use of land in urban areas. SDVs could eventually free up parking areas for alternate investment and development.²²⁶ Local

222. See MINN. H.R. PUB. INFO. OFFICE, NEW LAWS 1999: SESSION SUMMARY 3, 68 (1999), *available at* <http://www.house.leg.state.mn.us/hinfo/NL99.pdf>.

223. See, e.g., MINN. STAT. § 216C.05 (2014).

224. § 174.01 subdiv. 2.

225. See *generally* MINN. GO, MINN. DEP’T OF TRANSP., 20-YEAR STATE HIGHWAY INVESTMENT PLAN (2013), *available at* <http://www.dot.state.mn.us/planning/mnship/pdf/draftplan/mnship-draft-plan.pdf>.

226. See *supra* notes 157–59 and accompanying text.

governments should be ready to recapture these spaces for economic and social benefit. Certainly, cities and counties in Minnesota have already shown their willingness to let transit influence how their new construction and development decisions are made in a “transit-oriented” design process.²²⁷ These considerations can be applied in the SDV context as well to ensure that needed infrastructure is available for their use.

SDVs could have diverse impacts on more than just driving rules and statutes. As the technology is refined, testing becomes more widespread, and models become available for consumer use, policymakers will need to modify or enact rules to address and influence these broad implications.

227. *E.g., Transit Oriented Development*, HENNEPIN COUNTY, <http://www.hennepin.us/business/work-with-henn-co/transit-oriented-development> (last visited Mar. 1, 2015).
